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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAM

FOR THE

CAMBRIDGE MEETING

FEBRUARY 21–22, 1941

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

at

HARVARD UNIVERSITY

and the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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The American Physical Society

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of the

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AMERICAN PHYSICAL SOCIETY

CAMBRIDGE MEETING, FEBRUARY 21–22, 1941

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

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THE **240th regular meeting of the American Physical Society** is to be held at Cambridge, Massachusetts as a joint meeting with the Optical Society of America. The sessions of both societies will take place at the Massachusetts Institute of Technology on Friday, February 21st, and at Harvard University on Saturday, February 22nd.

A **joint session** of the American Physical Society and the Optical Society of America will be held on Friday morning, February 21st, at ten o'clock in Room 10–250 at M.I.T. It will consist of a symposium described as follows by the Optical Society: ". . . three invited papers dealing with different aspects of the subject of color. These invited papers will be profusely illustrated by lantern slides, motion pictures, and lecture-table demonstrations. They are intended to provide a broad survey of the advances made during the last decade in the field of color measurement and specification." Programs of this and the remaining sessions of the Optical Society may be had from its Secretary (Professor A. C. Hardy, M.I.T.) or may be found at the registration desk.

There will be a **joint dinner** of the two societies at the Hotel Commander on Friday evening, February 21st, at 7 o'clock. The President of the Physical Society, Dean George B. Pegram of Columbia University, will preside. The price of the dinner will be $1.75, fees included. Tickets will be on sale at the registration desk at M.I.T. Reservations must be made not later than three P.M. on Friday.

Luncheon may be had on Friday in the Dutch Room of the Graduate House at M.I.T.; or members may use the regular facilities of the Graduate House and of Walker Memorial. On Saturday the Harvard Faculty Club will be available for luncheon.

Tea will be served on Friday at the end of the afternoon session in the Forris Jewett Moore Room at M.I.T., and on Saturday after the afternoon session at the Research Library of the Physics Laboratory at Harvard.

The **Council** of the American Physical Society will convene at 2:30 P.M. on Friday in Room 10–200 at M.I.T.

For **hotel accommodations** the local committee recommends the Hotel Commander and the Hotel Continental. The rates at both hotels are $3.00 for single rooms; $4.00 for double rooms with double beds; and $5.00 for double rooms with twin beds. Members are urged to make their reservations at once, writing directly to the hotel.

GENERAL RULES RELATING TO PAPERS

By vote of the Society on December 27, 1940, no paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the American Physical Society not later than the closing date stated in the printed call for that meeting.

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The time allowed for the oral presentation of a contributed paper is ten minutes at most.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary program." (A paper by two or more members is credited to the one first named in its title.) For each paper on this program the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of these abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of *The Physical Review*.

Subsequent meetings of the Physical Society are as follows:

241. May 1–3, 1941. Washington, D. C.
242. June 18–20, 1941. Pasadena, California. Pacific Coast Meeting.
243. June 20–21, 1941. Providence, Rhode Island.

Sectional Meeting. The Secretary of the Southeastern Section of the Physical Society notifies us that its annual meeting is to be held on April 4–5, 1941 in Nashville, Tennessee at Vanderbilt University.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York, N. Y.

February 6, 1941.

CALENDAR

Friday morning, February 21st

10:00 o'clock: M.I.T.: Room 10–250: Joint session of American Physical Society and Optical Society of America: Symposium of invited papers: Speakers—Professor Arthur C. Hardy, Dr. David L. MacAdam, and Dr. Deane B. Judd.

Friday afternoon, February 21st

2:00 o'clock: M.I.T.: Room 10–250: Physical Society, Session A, Papers Nos. 1–9. See pages 5–7.

2:00 o'clock: M.I.T.: Room 10–275: Physical Society, Session B, Papers Nos. 10–18. See pages 7–9.

2:00 o'clock: M.I.T.: Room 6–120: Optical Society Papers Nos. 4–10. See Optical Society Program.

2:30 o'clock: M.I.T.: Room 10–200: Meeting of the Council of the American Physical Society.

5:00 o'clock: M.I.T.: Forris Jewett Moore Room: Tea.

Friday evening, February 21st

7:00 o'clock: Hotel Commander: Joint dinner of the societies.

Saturday morning, February 22nd

10:00 o'clock: Harvard: Large Lecture Hall, Jefferson Laboratory: Physical Society, Session C, Papers Nos. 19–27. (Supplementary Program: Paper No. 45 may be given at end of Session C if presiding officer so rules.) See pages 9–11.

10:00 o'clock: Harvard: Room 316, Cruft Laboratory: Physical Society, Session D, Papers Nos. 28–36. See pages 11–13.

10:00 o'clock: Harvard: Room 110, Pierce Hall, Engineering Building: Optical Society Papers Nos. 11–15. See Optical Society Program.

Saturday afternoon, February 22nd

2:00 o'clock: Harvard: Large Lecture Hall, Jefferson Laboratory: Physical Society, Session E, Papers Nos. 37–44. See pages 13–14. To be read by title: Papers Nos. 46–47. See page 15.

2:00 o'clock: Harvard: Room 110, Pierce Hall, Engineering Building: Optical Society Papers Nos. 16–19. See Optical Society Program.

5:00 o'clock: Harvard: Research Library, Physics Laboratory: Tea.

The American Physical Society

PROGRAM

FRIDAY MORNING AT 10:00 O'CLOCK

Massachusetts Institute of Technology

Room 10–250

SYMPOSIUM

OF

INVITED PAPERS

Spectrophotometry, a Basis for Color Measurement. ARTHUR C. HARDY, *Massachusetts Institute of Technology.*

Colorimetry and the Standard Observer. DAVID L. MACADAM, *Eastman Kodak Company.*

Color Perception and Its Relation to Color Measurement. DEANE B. JUDD, *National Bureau of Standards.*

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Massachusetts Institute of Technology

Room 10–250

Session A

1. Note on Liouville's Theorem and the Heisenberg Uncertainty Principle. J. H. VAN VLECK, *Harvard University.*—Both the Heisenberg uncertainty $\Delta p \Delta x$ and the infinitesimal domain in Liouville's theorem can be interpreted in terms of volume elements in phase space (areas for systems with one degree of freedom), but in the usual examples the uncertainty increases with time, whereas the Liouville volume is constant. In the case, for example, of a free particle moving in one dimension this discrepancy arises because an initially rectangular Liouville area is distorted into an increasingly oblique parallelogram as time progresses, and the Heisenberg uncertainty is usually measured by the area of the rectangle inscribing the parallelogram. To have a time invariant definition of uncertainty we must use in place of p, x the oblique coordinates $p'=p, x'=x-pm^{-1}t$ bounding the parallelogram. Classically the product $\Delta p' \Delta x'$ is obviously constant. This paper investigates whether the invariance also holds when quantum-mechanical operators are used. By transforming to momentum space it is proved that the invariance is also preserved in quantum theory. Thus, a formal definition of the Heisenberg uncertainty can be given which is independent of time, but it may not have much operational significance in terms of physical measurement. Details will probably appear in the *Philosophy of Science Journal.*

2. Reaction of the Absorber as the Mechanism of Radiative Damping. R. P. FEYNMAN AND JOHN ARCHIBALD WHEELER, *Princeton University.*—Radiative damping arises from retarded interactions between the various parts of an electron of finite size, according to Lorentz. At high frequencies this damping depends on the electron's structure. Non-electric stresses are required to hold the electron together. Dirac abandoned this picture and postulated a point electron. Guided by considerations of relativistic invariance he proposed essentially the first term in Lorentz's expression as a possible exact law for radiative damping. We postulate (1) that an accelerated point charge in otherwise charge free space does *not* radiate energy; (2) that, in general, the fields which act on a given particle arise only from *other* particles; (3) that these fields are represented by one-half the retarded plus one-half the advanced Lienard-Wiechert solutions of Maxwell's equations. In a universe in which all light is eventually absorbed, the absorbing material scatters back to an accelerated charge a field, part of which is found to be independent of the properties of the material. This part is equivalent to one-half the retarded field *minus* one-half the advanced field generated by the charge. It produces radiative damping (Dirac's expression) and combines with the field of the source to give retarded effects alone.

3. Statistics of the Two-Dimensional Ferromagnet. GREGORY H. WANNIER, *University of Texas.*—Rigorous statistical study of the Curie transition of ferromagnetics is possible for a two-dimensional square net of spins with coupling between neighbors. Kramers (unpublished), dealing with strips of spins infinite one way and finite the other, showed that the partition function λ is the largest eigenvalue of some finite matrix, $M(K)$, K standing for $1/kT \times$coupling energy between neighbors. (Order of matrix $=2^{n-1}$, $n=$number of spins along finite dimension.) Since ferromagnetism needs at least two infinite dimensions we want the limit of $\lambda(K)$ for large matrix order. The properties of M show that if λ possesses one singularity it lies at $K=0.4407$, where $\sinh 2K=1$. The energy there must be continuous and the specific heat can have no finite jump. For further study the specific heat is computed by matrix calculus. The numerical sequence of finite solutions increases as $\log n$. Consequently, the two-dimensional ferromagnet has an infinite specific heat at the Curie point.

4. On Position Measurements of Heavy Particles. O. HALPERN AND M. H. JOHNSON, *New York University.*—It has previously[1] been shown that a consistent application of relativistic quantum mechanics disproves the possibility of measuring exactly certain *individual* observables; e.g., the position of an electron or the component of an electric field strength. We have extended these deliberations to a discussion of the measurement of the position of heavy particles (protons). While the diversity of the possible arrangements does not allow a single sharp limit to the accuracy of observation to be given, it has been found that the minimum error involved is always close to the *electronic* rather than the protonic Compton wave-lengths.

[1] Paper submitted to *The Physical Review.*

5. Self-Consistent Field with Exchange for Si V and Si IV. MILLARD F. MANNING, *University of Pittsburgh,* AND W. HARTREE AND D. R. HARTREE, *University of Manchester, Manchester, England.*—Solutions of Fock's equations for the normal state of Si V and for a number of states of Si IV are reported. In Table I are shown the comparisons between the calculated and observed term values.

TABLE I. *Comparisons of calculated and observed term values for* Si IV.

	$3s$	$4s$	$5s$	$3p$	$4p$	$5p$
Calculated	359,400	168,800	98,000	289,600	144,100	87,000
Observed	364,100	170,100	98,700	292,500	145,700	87,500
	$3d$	$4d$	$5d$	$4f$	$5g$	
Calculated	201,800	113,400	72,200	109,800	70,240	
Observed	203,700	114,100	72,600	110,000	70,260	

TABLE II. *Comparison of calculated and observed doublet separations.*

	$3p$	$4p$	$5p$	$3d$	$4d$	$4f$
Calculated	430	149	70	19	9	2.3
Observed	460	162	75	small	small	1.3

The wave functions have been used to calculate spin-orbit interactions for the valence electron in different states. The results are given in Table II. It is noted that for the p states the agreement is satisfactory and hence the simple theory is a good approximation. For the d and f states the agreement is not satisfactory, indicating that the simple theory is not adequate.

6. Unexplained Irregularities in the Z Dependence of the Energy Differences Within the Configuration $3d^3$. J. E. MACK, *University of Wisconsin,* AND E. E. ANDERSON, *Milwaukee-Downer College.*—Of the 19 levels of the configuration $3d^3$, the 13 levels $^4FP\,^2GDH$ are well established experimentally from Ti II to Ni VIII, inclusive, in the scandium-like isoelectronic sequence. The graph of energy (with respect to $^4F_{3/2}$) against Z is, on the whole, so smooth that extrapolations can be made with an uncertainty of only about 100 cm^{-1}. In both Co VII and Ni VIII, however, ^2G and ^2H are almost 1000 cm^{-1} higher and ^2D almost 1000 cm^{-1} lower than would have been expected by extrapolation from Fe VI. This unexpected shift between VI and VII and the retention of the shifted value in VIII are the more puzzling in view of the large and smoothly increasing distance ($\doteq 3\cdot 10^5$ cm^{-1}) to the nearest neighboring configuration, $3d^24s$. The doublet separations behave smoothly. The phenomenon cannot be self-consistently expressed in terms of changes in the Slater integrals F_2 and F_4. (There are also smaller irregularities in ^4P, apparently unrelated to the foregoing, at the same values of Z.)

7. Term Energies in the Configuration d^5. OTTO LAPORTE, *University of Michigan.*—Among all configurations of equivalent d electrons the configuration d^5 will, because of its central position, give rise to the largest numbers of levels. However its complexity is somewhat lessened by the fact that in first approximation the spin orbit interaction vanishes for all of its terms. For the case of Russell-Saunders coupling the term energies have been computed as functions of three radial integrals F_0, F_2 and F_4. An unexpected simplification of the resulting formulae is that the quadratic equations for the two pairs of doubly occurring terms ($^2G_\pm$ and $^2F_\pm$) possess rational roots and that the cubic equation for the three ^2D terms possesses one root rational in the parameters. The comparison of these and similar formulae with the experiment is facilitated by a plot of relative term distances as a function of the parameter ratio $F_4 : F_2$.

8. General Considerations Concerning Term Energies of Configurations d^n. JOHN R. PLATT AND OTTO LAPORTE, *University of Michigan.*—When plotting formulae for d^n with F_2/F_4 as an independent variable it is seen that for $F_2 : F_4 = 5 : 1$ high order degeneracies occur. The five terms of d^2 and the eight terms of d^3 arrange themselves in three groups, while the sixteen terms of d^4 and d^5 coincide so as to form six superterms. The separations between these groups are all low multiples of $7F_2$. The formulae for d^4 as given by Ostrofsky[1] at first did not comply with this rule; a recalculation was therefore made and two errors were found in the expressions for the pairs $^1G_\pm$ and $^1S_\pm$. Analogous coincidences for the configurations f^n will occur for the

parameter ratio $F_2 : F_4 : F_6 = 11 : 6 : 1$. This behavior can be reduced to sum rules obeyed by the Condon-Shortly coefficients $c^k(lm; l'm')$.

[1] Phys. Rev. **46**, 604 (1934).

9. The Theoretical Extension of Large Air Showers. H. A. BETHE, *Cornell University.*—According to the theory of Euler and Wergeland, the scattering of electrons causes a shower to spread over approximately 30 meters in air of atmospheric pressure. The result of Auger and collaborators who found appreciable coincidences at distances of as much as 300 meters, was therefore interpreted as evidence for mesotrons forming the "wings" of large showers. This is in contradiction to experiments of Hilberry (unpublished) and Auger himself who showed that the radiation in the wings is much softer than in the core of a large shower. A more accurate calculation of the scattering of electrons was therefore made which gave 90 meters for the root-mean-square spread of a shower. The greatest contribution comes from the divergence of the "parent" γ-rays which created the observed electrons; the angular divergence of these γ-rays is due to scattering of the "grandparent" electrons. The electron density falls off more slowly than Euler's at large distances from the core of the shower; it increases more strongly (as $r^{-4/3}$) at small distances. A re-evaluation of Auger's experiments gives numerical results which by accident are very similar to his own and confirm the $E^{-1.9}$ law for the energy distribution of primary electrons.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Massachusetts Institute of Technology

Room 10–275

Session B

10. An Instrument for Studying the Topographies of Fine Textured Surfaces. F. W. ADAMS, LEE DEVOL, AND H. R. LETNER, *Mellon Institute of Industrial Research.*—A profilograph, using a tracing point and optical lever system, makes profiles of fine textured surfaces, magnifying the elevations and depressions by as much as 6000×. With this instrument it is possible to detect surface variations as small as 0.04 micron. It is also possible to make a series of profiles along parallel paths from which topographic or relief maps can be prepared. Uses include the study of machined, lapped, and etched surfaces of importance in industry. The high accuracy is obtained with no more difficult machine work than the simultaneous lapping of two tapered bearings mounted on a single shaft. The use of torsion elements of special design for supporting the mirror makes the instrument relatively insensitive to vibration. These torsion elements are capable of supporting a mirror large enough to permit several reflections of the light beam, giving the instrument its high resolving power.

11. The Input Impedance of a Symmetrical Antenna. RONOLD KING, *Harvard University.*—The input resistance and reactance of a symmetrical, center-driven, cylindrical antenna have been derived from the rigorous expression for the input impedance given by Hallén.[1] Resonance conditions and conditions for maximum input resistance have been derived in terms of the length and radius of the antenna. From these it can be shown that extreme values of the input resistance occur practically at resonance. Extensive curves for the input resistance and reactance as functions of the length and radius of the antenna and the driving frequency are being computed. A few typical cases have been completed and compared with the corresponding curves calculated by Labus[2] under the assumption of a sine current distribution. The new curves are a good approximation for all lengths and a wide range of radii, whereas all those based on a sine distribution of current are entirely incorrect over ranges of lengths near those for which they become infinite, and considerably in error for all but vanishingly small radii. The radii of many self-supporting ultra-high frequency antennas are sufficiently large to contribute appreciably to the input impedance.

[1] E. Hallén, Uppsala (1938).
[2] J. Labus, Zeits. f. Hochfrequenztech. **41**, 17 (1933).

12. A Magnetic Lens Beta-Ray Spectrometer. MARTIN DEUTSCH, *Massachusetts Institute of Technology.*—A beta-ray spectrometer has been constructed, utilizing the chromatic aberration of a "short" magnetic electron lens as proposed by Klemperer.[1] The resolution and "line shape" have been computed, assuming only spherical aberration to be important. The theory has been verified by experiment. The lens consists of a coil weighing about 300 lb., contains no iron, and uses up to 2 kw. The distance between source and counter can at present be varied from 1 to 2 meters. The greatest distance of the electron paths from the axis is 7.2 cm. "Line widths" of about 2 percent have been obtained, as well as solid angles of about 0.12. Neither value represents the limits of the instrument. The upper limit of energy is at present about 5 Mev for a length of path of about 2 meters. The large solid angle and the accessibility of the source make the instrument well suited for coincidence studies. First results on Br^{82} indicate a simple spectrum (above 0.14 Mev) as shown by coincidences, with a tentative upper limit of about 0.45 Mev and no internal conversion lines between 0.14 and 1.0 Mev.

[1] O. Klemperer, Phil. Mag. **20**, 545 (1935).

13. A Further Verification of the Montgomery Theory of Geiger Counter Discharge. W. E. RAMSEY, EMMETT HUDSPETH AND WAYNE L. LEES, *Bartol Research Foundation of the Franklin Institute.*—An investigation has been made with a specially designed counter whose cylinder consisted of nine insulated segments. With various known capacities between the counter wire and ground, families of curves were obtained in which the pulse-size was observed as a function of the number of segments whose potential was at a fixed point above the starting potential. Such families were obtained for both the so-called "non-quenching" (argon) and "self-quenching" (ether) gases. In the first case it was found that pulse-size was constant (equal to the overvoltage) for counter lengths less than a certain value. This critical length l is proportional to the total capacity of the counter wire. Beyond this length the pulse-size is proportional to l except for very small capacities. This behavior is precisely that predicted by the theory.[1] In the case of the "self-quenching" counter, pulse-size is proportional to counter length for all values of l and inversely proportional to the total counter wire capacity. These results constitute additional evidence that the quenching mechanism is exactly the same in the two types of counters,[2] and that the ether counter differs from the argon counter in that it does not break multiply.

[1] C. G. and D. D. Montgomery, Phys. Rev. **57**, 1030 (1940).
[2] W. E. Ramsey, Phys. Rev. **57**, 1022 (1940).

14. The Radiation of Light by High Current Electrical Discharges. J. W. FLOWERS, *General Electric Company.*—Currents of the order of 10^5 amperes produced by high voltage discharges in air radiate considerable light as well as sound. The apparent size of such a discharge as recorded by an ordinary photograph depends almost completely on the exposure, which may vary over a range of more than 10^4-fold. In an analysis of the light with respect to time, the resolution is in general limited by the effective size of the source which has previously been unknown. A transverse slit placed near the discharge path and acting as the light source has permitted resolution limited only by film speed. High speed rotating-film photographs of such a slit clearly show the variation of the luminous cross section of the discharge with time. Microphotometer analyses of such records show the relation of luminosity with the current as recorded by the cathode-ray oscillograph. With resolution known, departure of microphotometer records from current oscillograms in some cases can be ascribed to two factors, persistence of luminosity or deionization time and mechanism of discharge. This is supported by similar analysis of currents passing between electrodes in high vacuum which show very little persistence.

15. Rigidity and Internal Friction of a Glass in Its Softening Range. FRANCIS BIRCH AND DENNISON BANCROFT, *Harvard University.*—The rigidity of boron trioxide glass has been measured by a dynamical method to approximately 300°C. The softening or "transition" region for this glass begins at about 250°. For an interval of 50°, there now exist for the first time measurements of both rigidity and viscosity[1] for a given material, as well as rough estimates of the internal friction for torsional vibrations. Between 250 and 300°, while the viscosity decreases by a factor of about 1000, the internal friction increases by a factor of 5, and the rigidity decreases by about 25 percent. The internal friction is apparently independent of frequency between 4600 and 17,000 cycles per second. Absolute values for the elastic constants of this glass are also given. This work was inspired principally by certain geological problems, but the results should be of use in the construction of a physical theory of the vitreous state.

[1] G. S. Parks and M. E. Spaght, Physics **6**, 67 (1935).

16. Impedance of the Squid Giant Nerve Fiber During Current Flow. KENNETH S. COLE AND RICHARD F. BAKER, *Columbia University.*—The change in the transverse impedance of the squid giant nerve fiber caused by direct current flow has been measured at frequencies from 1 kilocycle to 500 kilocycles. The impedance change is equivalent to an increase of membrane conductance at the cathode to a maximum value approximately the same as that obtained during the passage of a nerve impulse and a decrease at the anode to a minimum not far from zero. There is no evidence of appreciable change of the membrane capacity in either case. The membrane is a rectifier with a rectification ratio of about 100 and is comparable with the Cu–CuO and Se rectifiers commercially available. Interpreting the membrane conductance as a measure of ion permeability, this permeability is increased at the cathode and decreased at the anode.

17. A New Method for Rapidly Desiccating Human Plasma for Transfusion Purposes. T. R. FOLSOM, *Memorial Hospital, New York City.*—The preservation of large quantities of human plasma for use for transfusions in war emergencies instead of blood has been advocated. It has been demonstrated previously that human plasma may be preserved by desiccating it from the frozen state, and that this may be reconstituted later by the addition of sterile water. The problem of supplying a sufficiently fast and economical vacuum pumping system for handling quantities of water vapor has already been solved by other workers. Because of the porous nature of dried plasma, and the low temperature permissible, heretofore heat could not be supplied rapidly enough to cause rapid evaporation, and ten to thirty hours drying time was necessary. Investigations into the thermal problem at the Memorial Hospital led to a method which permits complete drying in one hour. Plasma is injected into a rapidly pumped vacuum system so that small frozen granules are instantaneously formed by rapid evaporation. These granules fall into a vessel, which is warmed to body temperature and may be tumble-stirred. The granules remain frozen until dry and later may be poured out easily. The process permits design of apparatus about ten times faster than present equipment and permits continuously operating desiccators to be constructed if desired.

18. Measured Admittances of a Rochelle Salt Resonator. K. S. VAN DYKE AND MAYNARD C. WALTZ, *Wesleyan University.*—Bridge measurements of admittance of an

x cut, 45° Rochelle salt bar are made. The 20–50 kc range includes the long wave longitudinal resonance in the region covered, −40 to +40°C. Adherent foil electrodes are used, and as the resonator is mounted the Q is 1200 at −30°C. The resonator current is less than 1 ma/cm². Bridge balance is determined by nullity at the frequency of the source. The vector admittance circles pass almost through the origin and are centered very close to the axis of reals. To secure circular loci for temperatures between the Curie points the admittance must be measured at constant current through the resonator. For different values of current, circles are obtained which differ in diameter and in the distribution of frequency around the circle. Analysis of the circle corresponding to each temperature yields values of the dielectric, piezoelectric, viscous and elastic constants. The latter three are functions of the current for temperatures between the Curie points. d_{14} increases, while the resonance frequency and the Q decrease, with increasing current. The clamped dielectric constant is of the order of 50 even at the Curie points.

Saturday Morning at 10:00 o'clock

Harvard University

Large Lecture Hall, Jefferson Laboratory

Session C

19. The Nuclear Magnetic Moments of Ba^{135} and Ba^{137}. Robert H. Hay, *Columbia University.*—The "molecular beam magnetic resonance method"[1,2] has been used to measure the nuclear gyromagnetic ratios of the isotopes Ba^{135} and Ba^{137}. Only two resonance minima were seen. The ν/H ratio was constant for each and the g values obtained are 0.624 ± 0.002 for the deeper minimum and 0.558 ± 0.002 for the other, in units of $e/2$ Mc. The ratio of the depths of the minima was found from curves taken in rapid succession to be 1.9 ± 0.2; the ratio of the abundance of Ba^{137} to that of Ba^{135} is 1.89, using Aston's figures for isotope abundance.[3] Therefore, the value 0.624 has been assigned to Ba^{137} and 0.558 to Ba^{135}. Benson and Sawyer give 3/2 for the nuclear spin of both isotopes.[4] This leads to $\mu=+0.837\pm0.003$ nuclear magnetons for Ba^{135} and $\mu=+0.936\pm0.003$ nuclear magnetons for Ba^{137}. The ratio of the g values is also the ratio of the moments and is 1.1174 ± 0.1 percent.

[1] Rabi, Millman, Kusch and Zacharias, Phys. Rev. **55**, 526 (1939).
[2] Millman, Phys. Rev. **52**, 628 (1939).
[3] Aston, Proc. Roy. Soc. **134**, 571 (1932).
[4] Benson and Sawyer, Phys. Rev. **52**, 1127 (1937).

20. The Nuclear Magnetic Moment of In^{115}. T. C. Hardy, *Columbia University and College of the City of New York.*—The nuclear magnetic moment of In^{115} has been determined by the study of the radiofrequency spectrum of the ground state of the indium atom.[1] Lines characterized by transitions of the type $\Delta F=0$, $\Delta m=\pm1$, were observed. Since F has two values, each of the above transitions except those involving an m value of $\pm(i+\frac{1}{2})$ gives rise to a close doublet with frequency separation $2g_i\mu_0H/h$. The magnetic field, H, was calculated from the observed mean frequency of the doublet and the known nuclear spin and $\Delta\nu$ of the $^2P_{\frac{1}{2}}$ state of In^{115}. From observations of doublet separations in fields ranging from 400 to 4000 gauss the value of the nuclear magnetic moment is found to be 5.43 ± 0.03 nuclear magnetons. This is to be compared with the value of 6.40 nuclear magnetons found by Millman, Rabi, Zacharias,[2] using the atomic beam method of zero moments. The discrepancy is probably due to the difficulties inherent in the latter method.

[1] P. Kusch, S. Millman and I. I. Rabi, Phys. Rev. **57**, 765 (1940).
[2] S. Millman, I. I. Rabi and J. R. Zacharias, Phys. Rev. **53**, 384 (1938).

21. The Induced Radioactivity of Xenon. Edward P. Clancy, *Harvard University.*—The irradiation of xenon by 12-Mev deuterons produces activities of 68 minutes, 9.6 hours, and 5.4 days. Of these, the last is unambiguously due to Xe^{133}, since Wu[1] has found a 5-day period when activating the single isotope of caesium through an (n,p) reaction. In the present work this isotope has also been produced by irradiating tellurium with 24-Mev alpha-particles, through the reaction $Te^{130}(\alpha,n)Xe^{133}$. Such a bombardment yields as well a weak unassigned activity of lifetime a few hours. The 9.6-hour period is undoubtedly the same as Wu's 9.4-hour xenon[1] obtained from an (n,α) reaction on barium, and assigned by him to Xe^{135}. Therefore, it would seem most logical to assign the 68 minute activity to Xe^{127}. It is interesting that the 9.6-hour and 5.4-day periods correspond to xenon periods observed in uranium fission.[2,3]

[1] Wu, Phys. Rev. **58**, 926 (1940).
[2] Segrè and Wu, Phys. Rev. **57**, 552 (1940).
[3] Dodson and Fowler, Phys. Rev. **57**, 966 (1940).

22. Internal Conversion in Rhenium. G. E. Valley,* *Harvard University.*—A complicated spectrum of internal conversion electrons is found to be emitted by tungsten specimens after irradiation by 11-Mev deuterons. Approximately fourteen lines are observed in the region extending from 50 kev to 150 kev. Six of these lines indicate the emission of gamma-radiation of 86 kev, 101 kev and 135 kev, accompanying the decay of W^{187} (24-hr. half-life[1]). Five other lines indicate that gamma-

rays of 113 kev and 129 kev follow longer periods. These values are good to within 2 percent. Precision determinations, as well as a complete analysis, will be presented. The special methods used for preparing targets suitable for beta-ray spectrography will be described.

* National Research Fellow.
[1] K. Fajans and W. H. Sullivan, Phys. Rev. **58**, 276 (1940).

23. The Energy of the H^3 Beta-Ray. SANBORN C. BROWN, *Massachusetts Institute of Technology.*—The energy of the H^3 beta-ray has been measured by its absorption in helium. The detector was a screen cathode G–M counter. The source was mounted on a plunger sliding in a side arm on the counter envelope. The counter was operated with one atmosphere of helium flowing slowly through it at all times. The H^3, which was generously supplied by the Radiation Laboratory at Berkeley, was in the form of water. The source for the range determination was prepared by exposing a freshly distilled P_2O_5 surface to the H^3 water vapor in an atmosphere of helium for 24 hours. The maximum range of the H^3 beta-rays in helium was determined as 13 ± 1 mm. Using a range-energy relation of Schonland[1] and others, this corresponds to an energy of 9.5 ± 2.0 kev. The correction due to changes in solid angle with changing distance between the counter and source, and the correction due to the failure of the sensitive volume of the counter to coincide with the physical limits of the cathode screen, have been experimentally evaluated, and have been taken into account in the above value of the maximum energy.

[1] B. F. J. Schonland, Proc. Roy. Soc. **108**, 187 (1925).

24. Range of Fission Fragments. W. E. LAMB, JR., *Columbia University.*—The previous calculations[1] of the ranges in air of uranium fission fragments have been improved by the use of more accurate values for the successive ionization potentials of the fragments, and by inclusion of the energy loss due to nuclear collisions. Otherwise, the model was not changed. For an assumed initial total kinetic energy of 160 Mev, the ionization chamber ranges for the possible fragments $_{87}Kr^{36}$, $_{100}Mo^{42}$, $_{134}Sn^{50}$, $_{143}Ba^{56}$ were 2.25, 1.95, 1.94, 2.0 cm, respectively. These were assumed to terminate due to background when the energy loss per cm fell below 10 Mev/cm. (Energy of 5 Mev for Mo^{42}.) The residual ranges are then 1.40, 0.74, 0.84, 0.9 cm, respectively. The range for Kr^{36} is larger primarily because of its rare gas nature, since according to the model, the degree of ionization of the fragment depends on its ionization potentials. If fluctuations in charge are not too important, the division of the ranges into two groups may be due to the shell structure rather than the light mass and consequent high energy of the Kr^{36}.

[1] W. E. Lamb, Jr., Phys. Rev. **58**, 696 (1940).

25. The Scattering of Protons in Hydrogen from 200 to 300 kev. G. L. RAGAN, W. R. KANNE* AND R. F. TASCHEK, *University of Wisconsin.*—Observations have been made using two different scattering chambers. One had fixed counters at 15° intervals; the other had a pair of monitoring counters at 15° each side of the beam and a third counter which could be rotated to any position. Simultaneous counting is carried out with two different counters connected to similar amplifier-recording circuits. From these counts the ratio of scattering at the two positions is calculated directly. The counters are of the Geiger-Klemperer proportional type; several checks have been made of their performance. A study of the variation with energy of the observed 105°/60° scattering ratio for protons in helium was among these checks. A "differential pumping" system isolates the scattering chamber from the accelerating tube; a scattering pressure of about 1 mm of purified hydrogen is used. The counters are filled with purified hydrogen to about 35 mm pressure, separated from the scattering chamber by thin collodion windows. Variation of the scattering with energy and with angle has been studied. While the results are not yet entirely complete, they agree well with Breit's calculations based on a square well proton-proton interaction potential 10.500 Mev deep and $1e^2/mc^2$ radius.

* Now at Illinois Institute of Technology.

26. A Test of the Suggested Emission of Neutrinos Due to the Impact of Electrons on Heavy Nuclei. R. J. VAN DE GRAAFF AND W. W. BUECHNER, *Massachusetts Institute of Technology.*—Various investigators report from cloud-chamber experiments that the energy lost in the single scattering of 2-Mev beta-rays by heavy nuclei is several times the loss calculated from the Bethe-Heitler theory. However, Arcimovic and Chramov[1] find experimentally that the production of x-rays in this range agrees with theory. To account for the extra energy loss, Klarmann and Bothe[2] and Champion[3] have suggested the emission of neutrinos as well as x-rays. To test this hypothesis, a 2-Mev, 10-microampere beam of electrons was directed on a target immersed in 42 kg of mercury to absorb both heat and x-rays, the assembly acting as a calorimeter. The target holder could be shifted slightly for bombarding either beryllium or gold. Thus if an appreciable amount of energy is carried away by penetrating neutrinos when heavy nuclei are bombarded, the rate of heating in the calorimeter should decrease when the target is shifted from beryllium to gold. No perceptible change in heating has been observed, indicating the absence of the suggested[2,3] neutrino emission, at least in the case of gold.

[1] Arcimovic and Chramov, Comptes rendus de l'Acad. Sci. U.S.S.R. **18**, 415 (1938).
[2] Klarmann and Bothe, Zeits. f. Physik **101**, 489 (1935).
[3] Champion, *Reports on Progress in Physics* **5**, 348 (1939).

27. Non-Uniform Particle Density in Nuclear Structure. EUGENE FEENBERG, *Washington Square College, New York University.*—The Coulomb repulsion between protons must give rise to a tendency for the proton density to vary within a nucleus from a minimum value at the center to a maximum near the boundary. A non-uniform proton density may be expected to create forces which distort the neutron distribution and tend to make the two distributions vary in the same manner. If surface effects are neglected, it is possible to calculate the energy correction

associated with the non-uniform densities as well as the densities themselves in a comparatively rigorous and simple manner without making special assumptions about the nuclear forces. The neglect of surface effects permits the assumption that the variations in density are small departures from essentially constant distributions. It is found that the departure from uniform density is appreciable in heavy nuclei, but the energy correction is negligible. E. Wigner has obtained a similar result from another point of view.

Saturday Morning at 10:00 o'clock

Harvard University

Room 316, Cruft Laboratory

Session D

28. Granulation, Phase Change, and Microstructure. Melvin Avrami, *Columbia University.*—The theory of the preceding papers[1] is generalized and the notation simplified. A cluster of molecules in a stable phase surrounded by an unstable phase is itself unstable until a critical size is reached, though for statistical reasons a distribution of such clusters may exist. Beyond the critical size, the cluster tends to grow steadily. A comprehensive description of the phenomena of phase change may be summarized in phase change, grain-number, and structure formulas or diagrams, giving, respectively, the transformed volume, grain, and microstructure densities as a function of time, temperature, and other variables. To facilitate the deduction of formulas for these densities the related densities of the "extended" grain population are introduced. The extended population is that system of interpenetrating volumes that would obtain if the grains granulated and grew through each other without mutual interference. The extended densities are much more readily derivable from an analysis of the fundamental processes of granulation and growth. It is shown that, under very general circumstances, the densities of the actual grain population may be expressed simply in terms of the extended population.

[1] (a) J. Chem. Phys. **7**, 1103 (1939); (b) *ibid.* **8**, 212 (1940); Philosophy of Science, Technical Section **8** (Jan. 1941).

29. Critical Currents in Superconducting Films. W. F. Brucksch, Jr., W. T. Ziegler, E. R. Blanchard and D. H. Andrews, *The Johns Hopkins University.*—Semi-transparent films of tin and lead, 50 to 500 mμ thick, were deposited by evaporation on glass at room temperature and the following properties studied: variation of mean temperature (T_m) of superconducting transition zone with thickness, with magnetic field, and with critical current (I_c); variation of resistance with temperature within the zone. At about 2° below normal T_m, with a current (I) of about 125 ma, a steady state was maintained with $I_c - I = \Delta I = 0.0003 I_c$. An increase of 0.03 percent in current restored sufficient resistance so that the heat generated from the current caused a sudden rise in temperature and complete restoration of resistance in a kind of "trigger" effect. In this steady state, radiation from a small tungsten filament suspended above the film also produced the trigger effect. The intensity of radiation necessary to produce the effect rose sharply with increasing ΔI. Since the film acts as an energy amplifier, this suggests that the "trigger effect" might be useful for measuring radiation.

30. X-Ray Diffraction in Random Layer Lattices. B. E. Warren and J. Biscoe, *Massachusetts Institute of Technology.*—Heat-treated carbon black is an example of a material built up from individual layers which are parallel and equidistant but completely random in translation parallel to the layer, and in rotation about the normal. Calling the axes in the layer a, b and normal to the layer c, there will be sharp crystalline reflections of type ($00l$), two-dimensional lattice reflections of type (hk), and no reflections of type (hkl). A general theory for the intensity distribution in a two-dimensional lattice reflection has been developed. For a powder pattern the intensity of each two-dimensional reflection rises rapidly in a small range of angle, and then falls off slowly toward larger angles. The lateral dimension of the layer is given in terms of the half-maximum intensity breadth by the relation $L = 1.84\lambda/B \cos\theta$.

31. Absorption Coefficients in Lead for X-Rays Produced in the Voltage Range from 0.8 to 2.8 Mv. A. A. Petrauskas, F. E. Myers and L. C. Van Atta, *Massachusetts Institute of Technology.*—X-rays produced at high voltage were collimated into a narrow beam. The intensity was measured by means of a carbon-walled thimble chamber immersed in this beam. The geometry of the collimator and other details of the apparatus, together with tests for the proper performance of equipment, will be described. The x-ray intensity in the forward direction was found to vary approximately as the 3.0 power of the voltage reaching a value of 950 r per minute per milliampere one meter from the target at 2.8 Mv. Absorption coefficients were measured in lead for various voltages and filter thicknesses. The constant values obtained by using sufficient filtration are shown in the table. Initial values

Voltage (Mv)	0.8	1.0	1.4	1.8	2.2	2.8
Linear absorption coefficient	1.50	1.07	0.82	0.70	0.63	0.58

ranging from 2.9 cm^{-1} to 1.3 cm^{-1} at the lowest and highest voltages respectively were reduced to the constant values given in the table by using filter thicknesses ranging from ½ inch to 2 inches of lead.

32. Variation with Angle of the Intensity and Hardness of X-Rays Produced at 1.0, 1.8, and 2.6 Mv. L. C. Van Atta, F. E. Myers and A. A. Petrauskas, *Massachusetts Institute of Technology.*—The collimator and thimble chamber mentioned in the previous abstract were mounted to pivot about a horizontal axis through the x-ray target. The variation with angle of the intensity of unfiltered and heavily filtered radiation was measured for x-rays produced at 1.0, 1.8 and 2.6 Mv. At 2.6 Mv, x-rays filtered through one inch of lead show a ratio of intensity in the forward direction to that at right angles to the electron beam of 7.4. Definite evidence was obtained for the expected minimum in the forward direction. The variation of the absorption coefficient with angle was measured at 1.8 Mv. The absorption coefficient varies from 0.70 cm^{-1} in the forward direction to 0.85 cm^{-1} at 90°. A comparison of these results with available theory will be made.

33. The Effect of van der Waals Forces on the Thermal Diffusion Coefficient of Gaseous Isotopic Mixtures. R. Clark Jones, *Harvard University.*—The effect of attractive intermolecular forces on the value of the thermal diffusion constant α for a mixture of two isotopes has been worked out without approximation for the Lennard-Jones 9,5 model. A few of the computed results are given in the table.

$(\epsilon/kT)^{\frac{1}{3}}$	R_T	$(\epsilon/kT)^{\frac{1}{3}}$	R_T	$(\epsilon/kT)^{\frac{1}{3}}$	R_T
0.0	0.432	0.625	0.162	2.0	−0.465
0.1	0.463	0.833	−0.153	2.5	−0.232
0.25	0.475	1.0	−0.384	5.0	−0.040
0.5	0.324	1.5	−0.629	10.0	−0.023

R_T is the ratio of the computed value of α to that predicted by theory for hard elastic spheres, and ϵ is the depth of the potential energy minimum. In view of the approximate relation $kT_c=1.2\epsilon$, where T_c is the critical temperature, the table indicates that α passes through zero at the temperature $T=1.6T_c$. The reversal of the sign of α has not yet been observed experimentally. The experimental values of R_T determined by Nier for neon can be made to fall near the theoretical curve by using the value of ϵ indicated by the critical temperature, and by increasing the scale of R_T to account for the greater hardness of neon.

34. Estimation of Interaction Potentials from Molecular Scattering Experiments. I. Amdur and H. Pearlman, *Massachusetts Institute of Technology.* (*Introduced by F. G. Keyes.*)—Beams of helium atoms with kinetic energies equivalent to 300–1000 electron volts were scattered in helium gas and the axis intensities measured with a detecting system having an angular aperture of 2.5°. Total collision cross sections accurate to about 15 percent were determined as a function of beam velocity. The values varied from $3.3A^2$ at 300 volts to $0.9A^2$ at 1000 volts. The scattering, in the present case, is classical and due almost entirely to the mutual repulsion of two helium atoms. Attempts were made, therefore, to find a repulsive potential which could account for the experimental results. A hard sphere model, with a collision diameter derived from viscosity measurements, and a Lennard-Jones repulsive potential, $V(r)=4.45/r^{12}\times10^{-10}$ erg (r in A), were both found to be incorrect. The hard sphere model permits of no variation of cross section with velocity while the Lennard-Jones potential predicts but a slight difference in the values at 300 and 1000 volts. Moreover, in both cases predicted values are many times greater than experimental values. The "softer" exponential type potentials, $V(r)=Ae^{-a(r)^n}$, were more satisfactory and predicted cross sections whose values were quite sensitive to changes in A, a and n. The specific repulsive potential whose predictions are verified by the present experimental results is $V(r)=11.3e^{-4.63(r)^{\frac{1}{3}}}\times10^{-10}$ erg (r in A) for distances of interaction between 0.55 and 1.05A.

35. Dielectric Constants of Aliphatic Ketones. Robert H. Cole, *Harvard University.*—The static dielectric constants and densities of eight aliphatic ketones have been determined over nearly the entire temperature range of the liquid phase in each case. The dielectric constants were determined by a simple method making use of a cathode-ray oscillograph for quantitative comparison of impedances. The density measurements were made by a displacement method using a simple form of torsion balance. The experimental results show that dipole-dipole coupling is the important factor in determining the dielectric constants of these liquids. The results are in qualitative, but not quantitative, agreement with values calculated by Onsager's formula using known values of the dipole moments of the ketone molecules. The differences are, however, consistent with Kirkwood's extension of the Onsager theory to include the effect of correlation between orientations of neighboring molecules. An explicit calculation of this effect is unfortunately not possible in the case of the ketones.

36. The Surface Recombination of Hydrogen Atoms and Hydroxyl Radicals at Different Surfaces. W. V. Smith, *Harvard University.* (*Introduced by O. Oldenberg.*)—Atomic hydrogen was produced in a Wood discharge. The atoms were allowed to diffuse into a side arm coated with different substances. Among the advantages of a diffusion system was simplicity of mathematical analysis. The atomic concentration at a distance x from the discharge was measured by the heating of a small platinum probe. The ratio of atomic concentration at x to that at the discharge is $n/n_0=\exp-\beta\gamma^{\frac{1}{2}}x$. γ is the coefficient of recombination describing the catalytic power of the wall as a function of the temperature. β takes account of the probability that a

hydrogen atom hits the wall. The coatings are investigated at different temperatures. Probes coated with different substances are also compared. Values of γ range from 10^{-1} to 10^{-4}. They increase with increased temperature and decreased water content of the surface. Similar work was done with a water vapor discharge, detecting the hydroxyl radical by a potassium chloride probe which catalyzes hydroxyl recombination but does not catalyze atomic hydrogen recombination. Values of γ for hydroxyl lie in the same range as for atomic hydrogen.

Saturday Afternoon at 2:00 o'clock

Harvard University

Large Lecture Hall, Jefferson Laboratory

Session E

37. The Effect of Chemical Combination on X-Ray Emission Lines. T. M. Snyder, *Princeton University.*—Frequently, chemical combination affects the width, shape and wave-length of an element's x-ray emission lines even when the lines do not arise from transitions involving valence electrons. It is proposed that these effects are caused by electrostatic coupling between valence and x-ray electrons which splits x-ray levels and shifts their centers of gravity. The resulting fine structure of x-ray lines is unresolved but evidenced by a broadening and asymmetry dependent on the chemical state. Lines involving only deep-lying levels of heavy elements are unaffected. Slater's integrals calculated with approximate wave functions for iron group elements give roughly the observed splittings. L levels are affected far more than K and more by $3d$ than $4s$ electrons. When several $3d$ electrons with unpaired spin are present, the exchange interaction considerably exceeds the direct, giving $K\alpha$ line widths roughly proportional to the number of these electrons. A re-examination of existing data for behavior of widths and asymmetries as a function of atomic number, valence and ionic character verifies this rule. Furthermore, the number of unpaired $3d$ electrons predicted from line widths agrees with that obtained from magnetic data and gives interesting information about substances for which these data are lacking.

38. Secondary Structure in the Absorption Limits of Gases.* C. H. Shaw and J. A. Bearden, *Johns Hopkins University.*—The secondary structure in the K-absorption limit of germanium in gaseous $GeCl_4$ has been measured with the two-crystal spectrometer with a resolving power of about 10,000. The magnitude as well as the position of the structure was determined. The absorption edge of the isolated germanium atom should show no fine structure. This edge was assumed to have an arc tangent shape and a width the same as that for the isolated bromine atom.[1] The ratio of the absorption coefficient of Ge in $GeCl_4$ to that of the free atom was then calculated as a function of the separation from the limit and compared with theory.[2] Considering the number and character of the approximations involved in the theory, the comparison is satisfactory.

* This research was supported by a grant-in-aid from the Research Corporation.

[1] Shaw, Phys. Rev. **57**, 877 (1940).
[2] Hartree, Kronig, Petersen, Physica **1**, 895 (1934).

39. Saturation Magnetization of Nickel-Antimony and Nickel-Tantalum Alloys. G. T. Rado and A. R. Kaufmann, *Massachusetts Institute of Technology.* (*Introduced by John C. Slater.*)—The absolute saturation magnetic moment per atom (M) was measured as a function of the atomic composition (τ) for nickel-antimony and nickel-tantalum solid solutions. Five alloys of each set were prepared, up to $\tau = 7$ percent. They were cast in vacuum and carefully annealed. The specimens were small spheres, $\frac{1}{16}$ of an inch in diameter. The magnetization was measured by means of a Curie method in a solenoidal electromagnet. Field strengths up to 40,000 gauss and temperatures down to 77.2°K (boiling N_2) were used. A "superposed paramagnetism" was found in some samples at 290°K and 194.5°K, but the high field strengths permitted an accurate determination of the intrinsic magnetization. Up to about $\tau = 4$ percent, $dM/d\tau$ is strictly constant and equal to -3.60 and -5.66 Bohr magnetons (μ_B) per substituted atom for Ni-Sb and Ni-Ta, respectively. The Ni-Ta results are new. Those on Ni-Sb are in disagreement with Sadron[1] and Marian,[2] but our data appear to be more consistent. The two measured $dM/d\tau$ values are definitely different and not equal to $-5\mu_B$ per substituted atom as "predicted" by the energy band theory.[3,4] A complete tabulation of $dM/d\tau$ for nickel alloys shows our results to be additional exceptions to a surprisingly large range of applicability of the theory.

[1] C. Sadron, Ann. de Physik **17**, 371 (1932).
[2] V. Marian, Ann. de Physik **7**, 459 (1937).
[3] J. C. Slater, Phys. Rev. **49**, 537, 931 (1936).
[4] R. M. Bozorth, Bell Sys. Tech. J. **19**, 1 (1940).

40. Magnetization of Copper-Nickel Alloys. A. R. Kaufmann and C. Starr, *Massachusetts Institute of Technology.*—The magnetization in fields up to 30,000 oersted of copper-nickel alloys ranging in composition from pure copper up to 50 percent nickel has been measured at

various temperatures between 14°K and 1300°K. The 50 percent alloy becomes ferromagnetic between 77°K and room temperature but an alloy with 38 percent nickel does not exhibit a real ferromagnetic behavior even at 14°K. This latter alloy as well as one with 30 percent nickel does show large saturation effects at low temperatures, but the susceptibility of the specimens with 20 percent nickel and less is independent of field strength at all temperatures. At the lowest temperatures employed the susceptibility at any composition including "pure" copper shows an increase with decreasing temperature but a Curie-Weiss law is approximated only for the alloy with 50 percent nickel. In general, the lower the temperature and the higher the composition, the more nearly a Curie-Weiss behavior is approached in the alloys which do not become ferromagnetic. At high temperatures, the susceptibility of all compositions up to 30 percent nickel begins to increase again, although the effect is generally small compared with the low temperature increase. This behavior leads to a minimum in susceptibility at a certain temperature which becomes higher as the nickel content increases.

41. An Electron Configuration Change in Metallic Zr from Magnetic and Resistance Measurements. C. F. SQUIRE AND A. R. KAUFMANN, *Massachusetts Institute of Technology.*—According to theory, the paramagnetic susceptibility of electrons in a metal should decrease slightly with raising the temperature. For pure, ductile Zr, our experiments show that the paramagnetism increases with rising temperature from 80°K up to 1000°K in a linear manner. Above this temperature the susceptibility rises in a non-linear manner until at 1120°K it shows a λ point where the crystal is known to undergo a structure change.[1] Above the λ point the paramagnetism shows normal temperature dependence. We account for these and the following data by supposing that the density of electrons at the top of the filled energy states is continuously increasing. The electrical resistance was found to rise with temperature so that dR/dT became smaller and approached zero as T approached the λ point. In accord with Zwikker[2] the resistance then drops at the structure change and then rises linearly with temperature on beyond. As much as 1.36 mols of atomic hydrogen could be dissolved in a mol of Zr, increasing the volume about 8 percent, giving the specimen some unusual magnetic properties, and lowering the transition temperature to 960°K.

[1] W. G. Burgers, Physica **1**, 561 (1934).
[2] C. Zwikker, Physica **6**, 361 (1926).

42. Paramagnetic Relaxation. C. STARR, *Massachusetts Institute of Technology.*—The dynamic magnetic susceptibility of paramagnetic salts in an alternating magnetic field can be approximately described as a function of frequency by a simple dispersion formula,[1] based upon the thermal coupling between the ionic spin-system and the lattice vibrations. This dispersion is characterized by a relaxation time which is increased by a decrease of temperature or by the application of a constant parallel magnetic field. The experimental results obtained with the iron-group alums[2] agree only qualitatively with the theoretical dispersion formula. The discrepancies may be due, in part, to uncertain experimental conditions and to errors inherent in the methods used. These will be discussed in detail. The results at liquid helium temperatures are complicated by the fact that the specific heat of the crystal lattice is comparable to that of the spin-system. At higher temperatures, the errors associated with the high frequency beat method used in these experiments have been neglected. With suitable changes in the experimental technique to minimize the errors, measurements made at liquid hydrogen temperatures should be most valuable for the investigation of this subject.

[1] Debye, Physik. Zeits. **39**, 616 (1938).
[2] Gorter, Brons, Teunissen, de Haas, *et al.* Physica, 1936–1940.

43. Scattering, Trapping, and Release of Electrons in NaCl and in Mixed Crystals NaCl-AgCl. A. VON HIPPEL AND G. M. LEE, *Massachusetts Institute of Technology.*—The dielectric strength of ionic single crystals increases rapidly with temperature, reaches a maximum, and decreases again. In glasses the low temperature dependence is absent or reversed. That the periodic order produces a positive temperature coefficient can be explained by electron scattering, but a new mechanism must be held responsible for the steep decrease of the breakdown strength at higher temperatures. Studying mixed crystals of NaCl and AgCl containing zero to fifteen atomic percent silver between −150°C and +150°C, we found new facts: At low temperatures the breakdown characteristic of pure NaCl and of the mixed crystals has about the same positive slope; increasing silver content displaces the curves to higher breakdown values. The higher the silver concentration, the sooner the dielectric strength reaches a maximum and the steeper is the negative slope thereafter. Consequently the curves cross; and while at room temperature the electric strength of rock salt is increased by the addition of silver, the opposite is true at 150°C. The possibility of thermal breakdown can be excluded experimentally. We believe that the trapping of electrons and their release by lattice vibrations are the additional mechanisms shaping the characteristics as observed. Spectroscopic evidence supports this hypothesis.

44. The Conductivity of Glass as a Function of Field Strength. R. J. MAURER, *Massachusetts Institute of Technology.*—The conductivity of soda-lime glass has been measured, as a function of field strength, between 0°C and 110°C. The data are compared with a recent theory of electrolytic conductivity of solids.[1] With field strengths less than 7×10^5 volts/cm, the equation

$$i=\frac{2ned}{\alpha\nu^2}\left(\frac{kT}{h}\right)^3\exp\left(-\frac{U}{kT}\right)\sinh\left(\frac{ed(\epsilon+2)E}{6kT}\right)$$

describes the dependence of the current density upon field and temperature. The three atomic parameters, the frequency ν, the activation energy U, and the jump distance d can be determined and have the expected magnitudes. It is suggested that, for crystalline materials, where d is known, the validity of the Lorentz-Lorenz correction to the inner field can be tested.

[1] F. Seitz, *The Modern Theory of Solids* (McGraw-Hill).

SUPPLEMENTARY PROGRAM

45. A General Nuclear Model.* EUGENE FEENBERG, *Washington Square College, New York University.*—A useful nuclear model is provided by the approximation in which the Coulomb interaction is neglected and the energy is expressed in terms of volume and surface energy densities which are symmetrical functions of the mean particle densities. With this model the energy can be represented rigorously by a linear combination of functions

$$A^{n/3}f_n(|N-Z|/A)$$

with n ranging in integral steps from 3 to $-\infty$. The terms with $n=3$, 2, 1 have simple physical interpretations. The radius is expressible as a linear combination of the same kind of function met with in the representation of the energy, but, in this case, n ranges in integral steps from 1 to $-\infty$. If E is the total energy, and E_s the surface energy, the following differential equation holds:

$$E(NZ)=\left(N\frac{d}{dN}+Z\frac{d}{dZ}\right)E(NZ)+\tfrac{1}{3}E_s(NZ).$$

* To be called for after Paper No. 27, Session C.

Papers to be Read by Title

46. Temperature Distributions in Hollow Cylindrical Systems. MELVIN AVRAMI, *Columbia University.*—The equations for the steady-state temperature distributions in a hollow cylindrical system with a cylindrically symmetric, but otherwise non-uniform, heat source on the hollow surface, are set up and solved in Fourier integral form. Such a system may be an electric or "muffled" combustion type of furnace, in which only conduction and radiation need be taken into account. The boundary value problem is novel in that it involves radiation at a non-uniform temperature. The solution gives the relation between density of heat source and resulting temperature distribution. It may be used to solve such practical problems as that of designing an *isothermal furnace*, i.e., determining the distribution of source density which will give a uniform temperature over a finite length.

47. Time Lag Studies in Geiger Counters.* M. E. ROSE AND W. E. RAMSEY, *Bartol Research Foundation of the Franklin Institute.*—As an explanation of the inefficiency of air and oxygen counters, it has been proposed that the electrons are captured before the discharge is initiated and time lags are introduced due to the low mobility of the negative ions. To test this hypothesis we have measured the efficiency of an oxygen counter (diameter 2.7 cm) as a function of amplifier resolving time with a triple coincidence circuit using small parallel counters as explorers. For a fixed distance of the explorers from the wire of the central oxygen counter, the efficiency is constant and small (25 percent) at low resolving times, increases for intermediate resolving times ($\sim 10^{-5}$ sec.) and approaches a constant larger value (80 percent) for long times. As the explorers are moved toward the wire of the oxygen counter the time lags are reduced in accordance with the capture hypothesis. From the results obtained with the exploring counters just overlapping the oxygen counter, we find the mean time lag is 4×10^{-5} second, the probability for capture before the electrons reach the wire is 90 percent, the capture probability per impact is $\sim 10^{-4}$ and the mobility of the O^- ions is 2 cm²/sec./volt in agreement with direct measurements of these quantities.

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